Observations of single electron trapping/detrapping events in tunnel oxide of SuperFlash® flash memory cell

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Abstract

It is known that charge trapping in charge-transfer dielectrics is a limiting factor of program/erase cycling endurance of non-volatile floating gate memories. The understanding of charge trapping/detrapping kinetics is therefore needed for development of optimized program/erase schemes and cell design.

Stacked-gate cells during cycling usually show a gradual degradation of program-erase threshold voltage window due to electron trapping in tunnel oxide. In contrast to this, SST SuperFlash® cell gives us an opportunity to observe a fine structure of electron trapping/detrapping kinetics. The dependence of cell read current vs. the number of program/erase cycles clearly shows the modulation of cell erase characteristics due to trapping and detrapping of single electrons in the tunnel oxide (Fig.1). This observation became possible due to unique structure of SuperFlash® cell, which uses a floating gate injector tip providing a strongly localized Fowler-Nordheim tunneling during erase operations.

We also observe an effect similar to erratic erase phenomenon in stacked-gate flash memory – random bidirectional variations of cell read current between consecutive program/erase pulses. While these variations in stacked gate memories are thought to be a result of anode hole injection and subsequent hole trapping and detrapping, our results show that in the SuperFlash® cell they are due to single electron trapping and detrapping to/from neutral or positively charged traps. Moreover, as opposed to stacked-gate flash cells, where hole injection-induced erratic erase behavior may eventually result in overerase event, SuperFlash® cell is immune to overerase due to its split-gate structure. We also don't see any sign of anode hole injection in a SuperFlash® cell which can be explained by lower anode field and thicker tunneling barrier for holes during erase.

In the paper we will show the examples of single electron trapping/detrapping events in SuperFlash® cell as well as present some models explaining the experimental data.

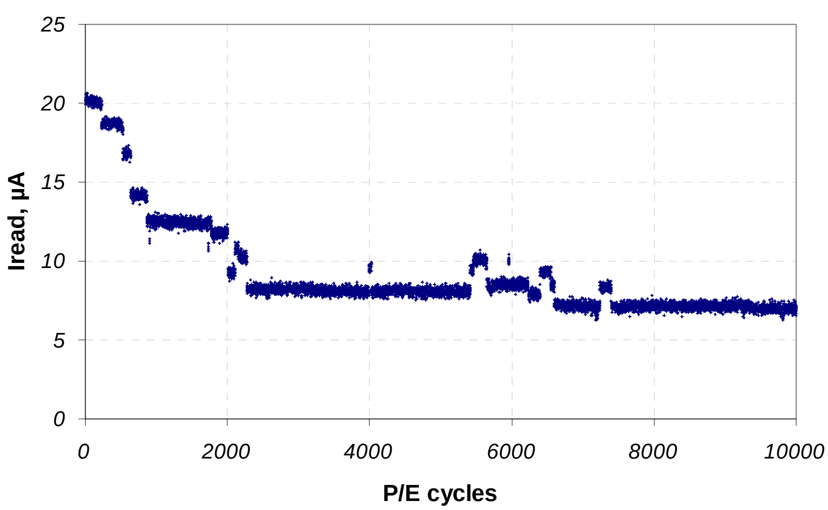

Fig.1. Fine structure of cell current (*Iread)* during Program/Erase cycling showing single electron trapping/detrapping events. Weaker erase conditions were intentionally used during cycling to enhance the effect of erase modulations on cell current.